

Watt Saver Zero No-Load Power AC/DC Converter

Contents

1 Introduction

This user guide describes the steps for getting started with the Watt Saver demonstration, the basic board function, and contents.

Innovative Watt Saver no-load technology for AC adapters prevents wasting power when no device is connected. Freescale Semiconductor is finding innovative ways to prevent “vampire” energy loss, that is, the loss of power that occurs when an AC adapter is plugged into an electrical outlet but isn’t charging a device. Freescale’s new Watt Saver technology automatically eliminates no-load power consumption for AC adapters, potentially providing substantial energy savings over existing manual versions. Freescale’s Watt Saver technology consists of patent-pending hardware and software implementations enabling the main power source to be disconnected when no power is required by the connected device.

1.1 Demo board features

The watt saver demonstration board includes the following features:

- Support for 110 V and 220 V.
- Discrete H-Bridge.
- 1 F –5.5 V super cap

1	Introduction.....	1
1.1	Demo board features	1
2	Demo board application block diagram	2
2.1	Modules explanation.....	2
3	Demo board content.....	3
4	Watt Saver demonstration board.....	5
4.1	Getting started with Watt Saver demo board	5
4.2	Demo board operation modes.....	6
4.3	State diagram.....	6
4.4	Operating parameters	7
4.5	Current measurement (GND-shield cables)	8
4.6	Average power consumption.....	8
4.7	Troubleshooting.....	9
5	Conclusions.....	10
6	References.....	10
7	Revision history.....	10

Demo board application block diagram

- Support common and ground (GND)-shield USB cables.
- Device end-of-charge detection (cell phone, tablet, mp3 player).

NOTE

A GND-shield cable is a cable with GND and shield tied together on the cable.

2 Demo board application block diagram

This figure shows the application block diagram of WATTS-AVER-EVB (where EVB stands for Evaluation Board).

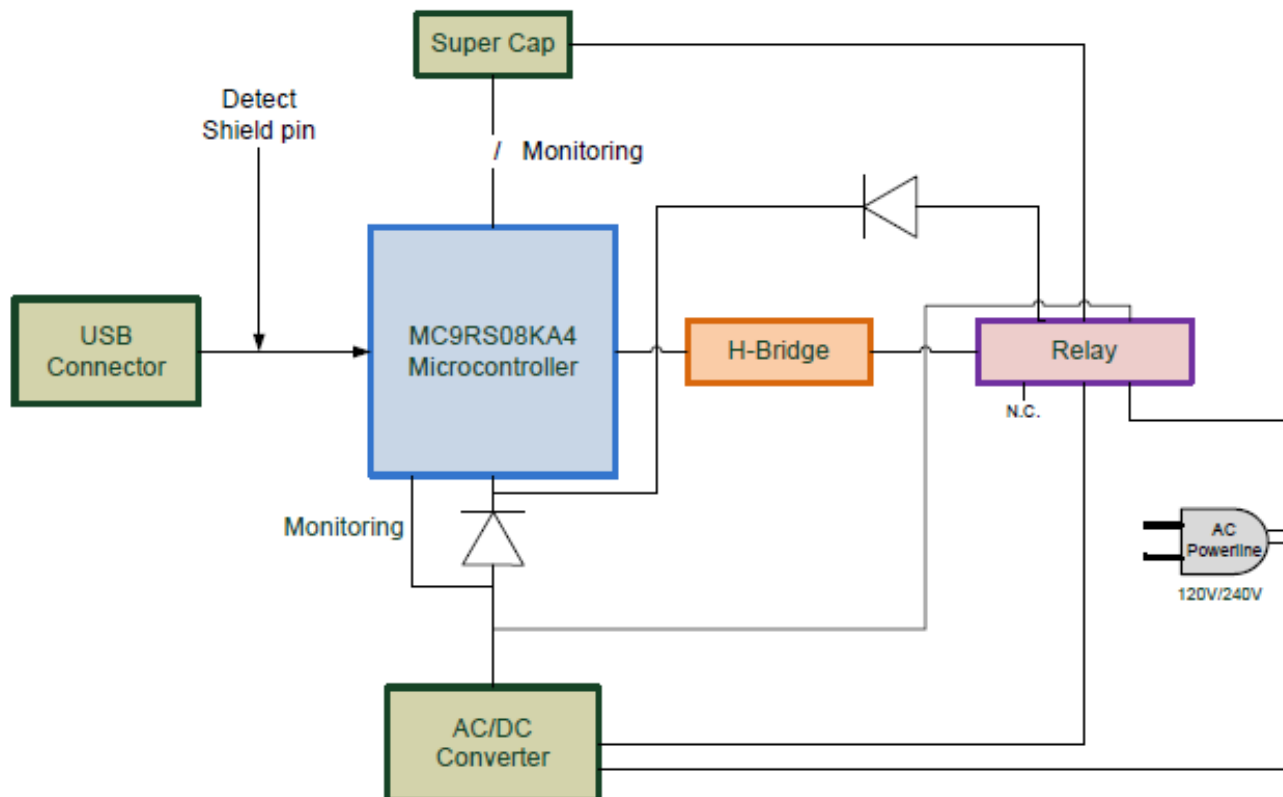


Figure 1. Application block diagram

2.1 Modules explanation

Microcontroller (MCU)

The MC9RS08KA4 microcontroller is used to control all operational modes, current, voltage measurements, and GND-shield detection.

The following are the MCU modules used in this application:

- Analog comparator (ACMP)
- Keyboard Interrupt (KBI)
- Real-Time Interrupt (RTI)
- 10 bit Analog to Digital Converter (ADC)

Discrete AC/DC Converter

This module has the following characteristics.

- Input — 110 – 220 V
- Output — 5 V / 1 A

Super Cap

Super cap is the power supply for Watt Saver when it is in low-power mode. It is used instead of a battery. This is a 1 Farad, 5.5 Volts super cap.

H-Bridge

Discrete H-bridge is created with two complementary pair enhancement mode field-effect transistors. H-bridge is used to generate the control signal needed to switch Relay between AC mode and low power mode.

Relay

A bistable coil type relay is used to disconnect the AC power line to the rest of the circuit when the Watt Saver is in low-power mode. This component has the following characteristics:

- Bistable coil type
- 110/220 VAC compatible
- 2.4 VDC rated voltage

3 Demo board content

The Watt Saver demo board contains several blocks needed for the implementation of a no-load AC charger. The main blocks and components of this demo board are highlighted in the following figures.

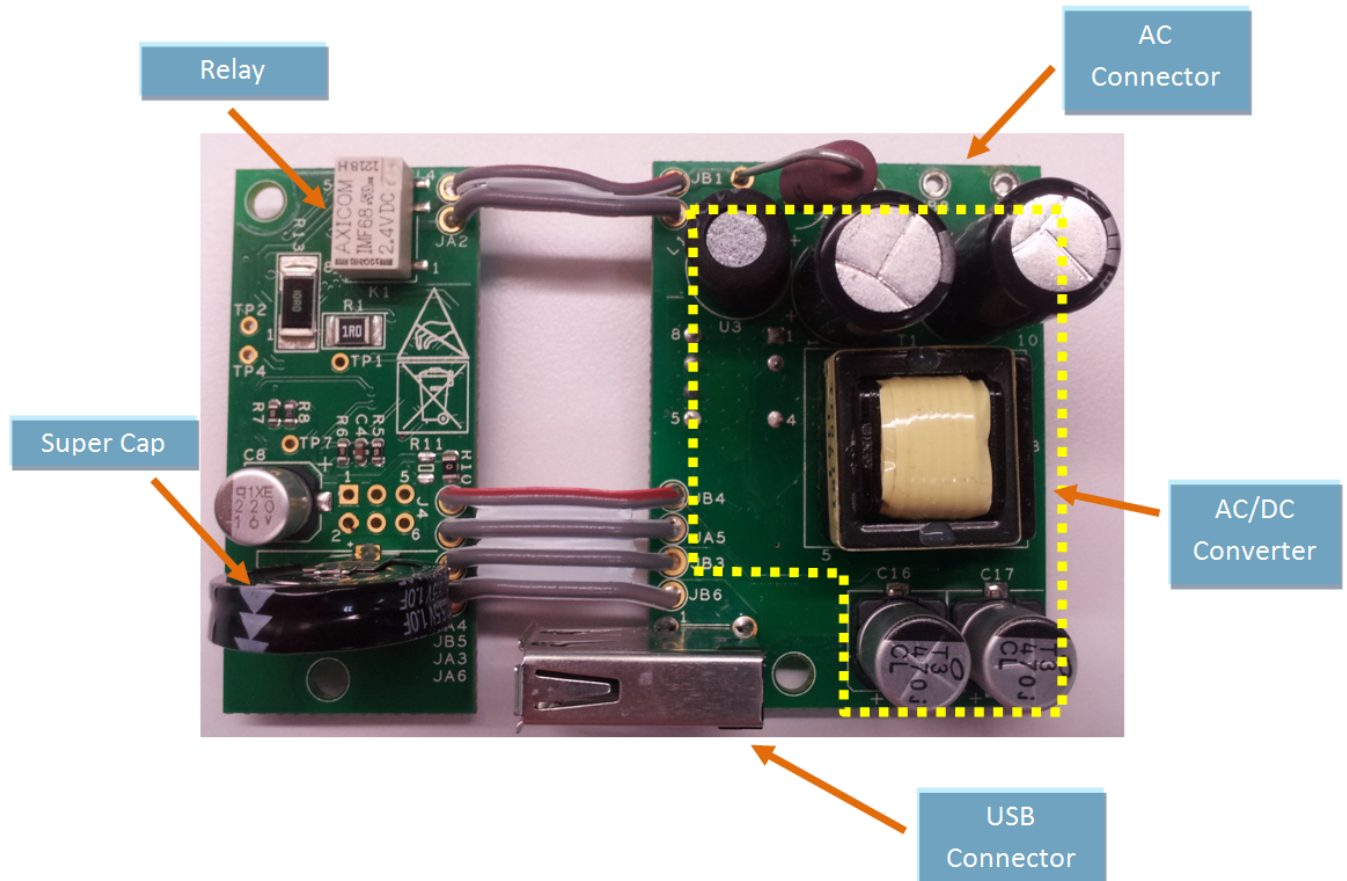


Figure 2. Watt Saver demo board content (inside)

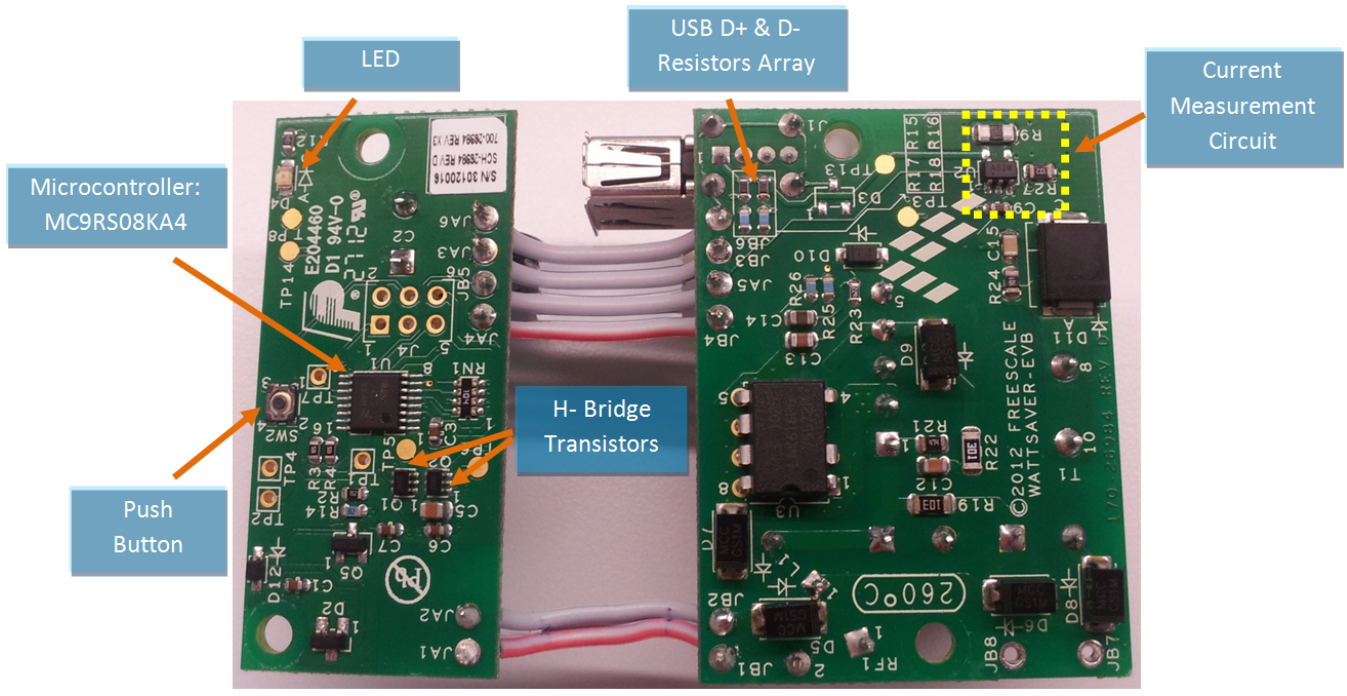


Figure 3. Watt Saver demo board content (outside)

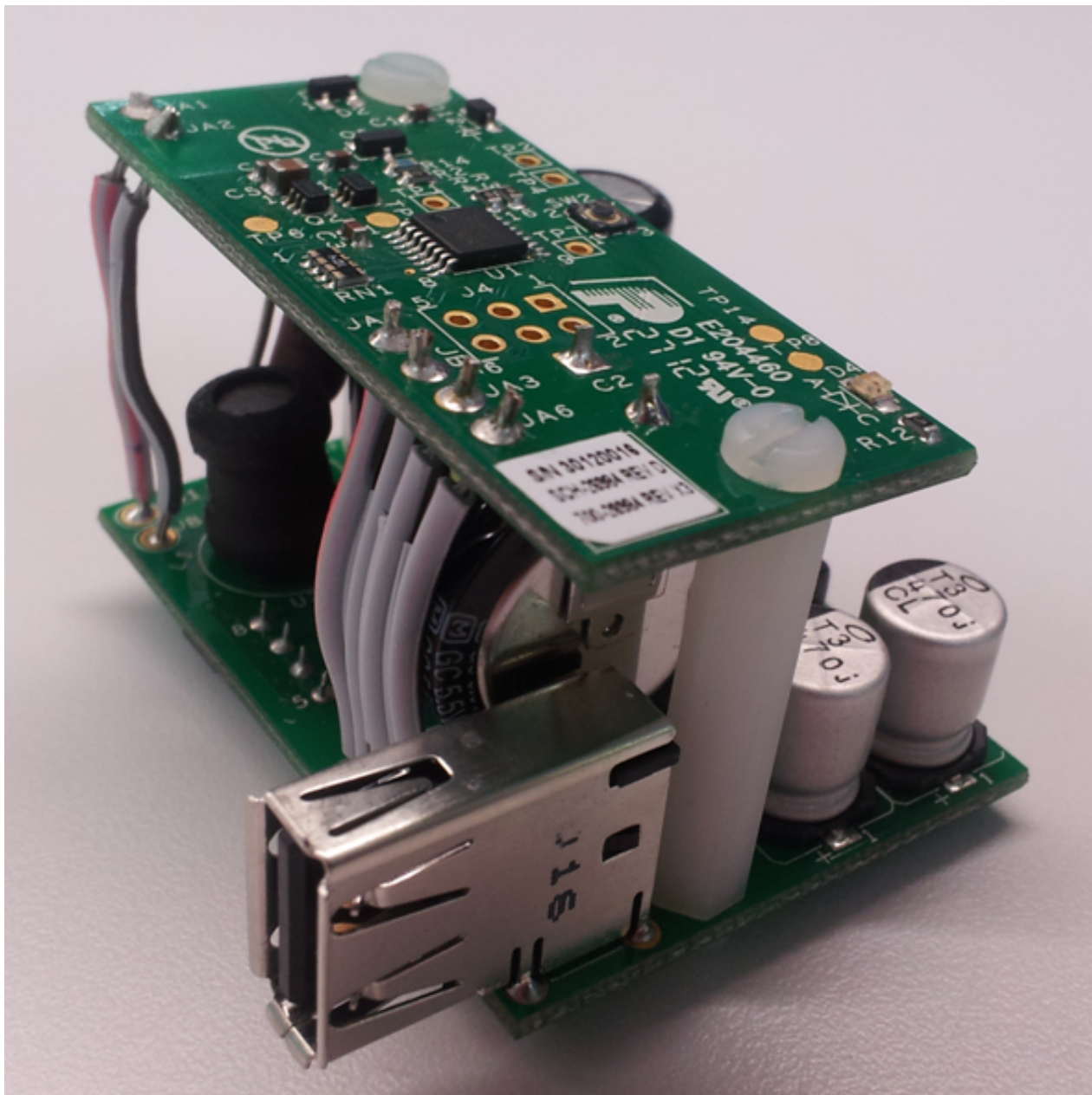


Figure 4. Watt Saver demo board assembled

4 Watt Saver demonstration board

Watt Saver software control includes several operation modes, operation parameters, and features that will be explained in this section.

4.1 Getting started with Watt Saver demo board

The Watt Saver works as a common device charger; just connect it to the AC line and it will start charging your device. If the device is not connected or it is charged and super cap is fully charged, then the Watt Saver will switch the relay and start saving energy.

4.2 Demo board operation modes

The Watt Saver has three operational modes:

- AC mode—The Watt Saver remains in this operational mode when a device is connected and charging or when the super cap is not fully charged. The LED remains turned on.
- Low-Power mode (super cap mode) —The Watt Saver switches to this operational mode when a device is not connected and super cap is fully charged. Any device or GND-shield cable connection wakes the Watt Saver and switches to AC mode. A plug-in detection is performed every second and the supercap voltage is monitored every 8 seconds. The LED remains turned off.
- Wait Cable mode —The Watt Saver switches to this operational mode when the super cap is fully charged and one of the following conditions occurs:
 - The device is connected and device battery is fully charged.
 - Only the GND–shield cable is connected and the device is not.

If device or GND-shield cable is disconnected, then the Watt Saver switches to super cap mode.

If the Watt Saver detects a low voltage in the super cap, then it will switch to AC mode.

The Watt Saver will return to AC mode periodically to sense device current measurement and start charging the device again, if needed. LED turns on periodically every 20 minutes.

4.3 State diagram

The following state diagram shows the operational modes for the Watt Saver demo board.

Watt Saver remains in this operational mode when a device (cell phone, tablet, MP3) is connected and charging or when the Super Cap is not fully charged.

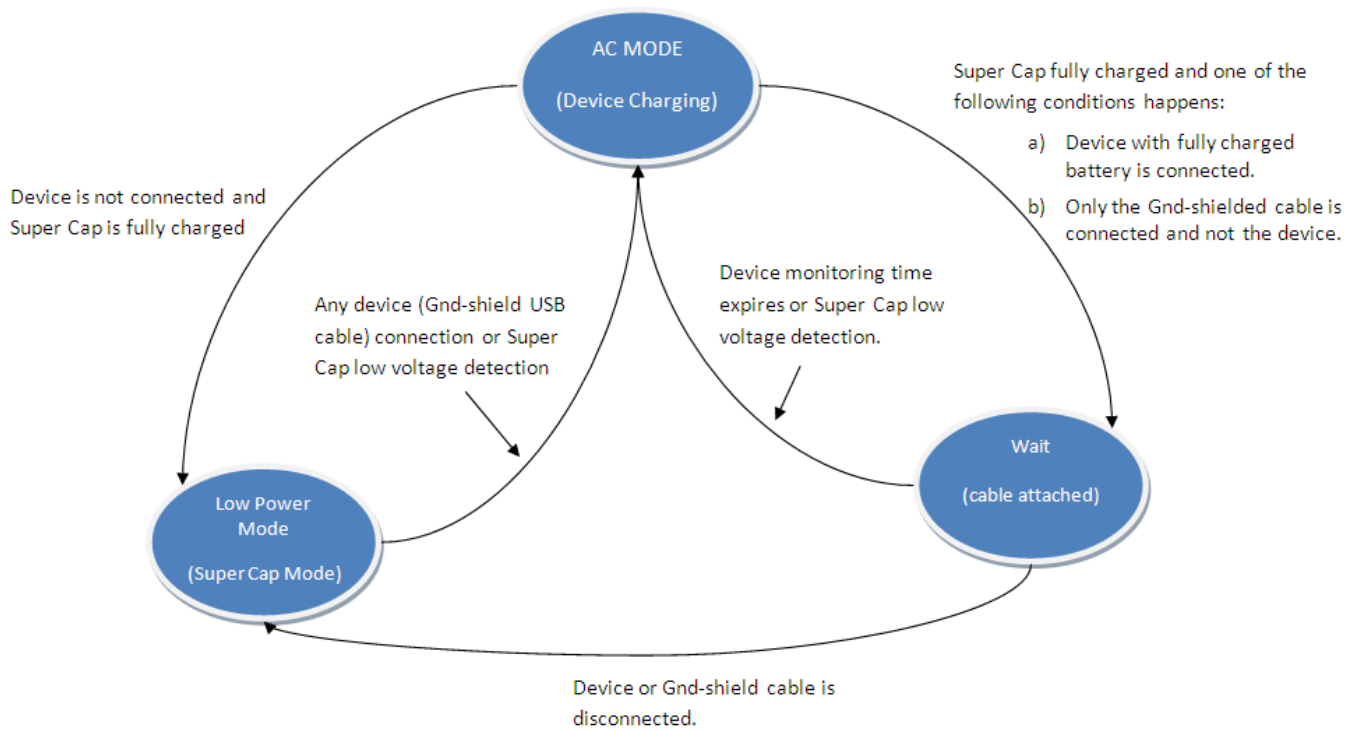


Figure 5. State diagram

4.4 Operating parameters

Table 1. Operating parameters

Parameter	Measurement	Notes
Super cap charge time	~ 1 minute	Watt Saver takes only one minute to charge the 1 Farad super cap up to 4.7 Volts.
Super cap discharge time	~ 15 days	Watt Saver takes 15 days to discharge super cap up to 2.3 Volts. This voltage is needed to switch the relay to AC mode.
Watt Saver current consumption in AC mode without device connected	~ 6.5 mA	This is the current consumption while super cap is charging and the device is not connected.
Watt Saver current consumption in low power mode	0 A	Watt Saver is disconnected when no power is required by the connected device.
MCU current consumption in low-power mode	~ 1 µA	This is the average current consumption in low power mode. The MCU is working with the voltage stored in the super cap, this way it does not waste energy.

4.5 Current measurement (GND-shield cables)

One of the most relevant features is the end-of-charge detection and the ability to support ground-shield cables. The way Watt Saver detects a device based on the union of GND and shield, which occurs when the device is connected to the cable, although currently some cables have this union without any device connected.

This feature is implemented using a 10-bit ADC and the current measurement circuit which includes an amplifier that increases the measurement resolution. The Watt Saver detects when a cable is connected to the USB connector and the current is measured to determine if there is any connected device. The highest and the lowest current values can be selected via software, this means that the Watt Saver can be tuned up for specific or generic devices.

The actual operation ranges are:

Device charging — 210 mA DC or higher

Device fully charged — 170 mA DC or lower

4.6 Average power consumption

The average power consumption for the Watt Saver using a discrete AC/DC converter is given in this table.

Table 2. Average power consumption

AC/DC Converter	AC/DC Converter Average power Consumption - No Load			AC/DC Converter plus the Watt Saver Average power Consumption - No Load			Power Saving Percent
	Current Consumption (mA)	Active Time Percent	Power Consumption (mW) at 110 VAC	Current Consumption (mA)	Active Time Percent	Power Consumption (mW) at 110 VAC	
Watt Saver (10 W)	15	100 %	1650	15	0.024 %	0.38	99.97
Watt Saver zero no-load power AC/DC converter (5 W)	1.2	100 %	132	6.5	0.005 %	0.03	99.97

These numbers were obtained as follows:

- Power consumption for the AC/DC converter with 100 % active time
 $P = IV$, so $P = (1.2 \text{ mA}) * (110 \text{ V}) = 132 \text{ mW}$
- Active time percent AC/DC converter plus the watt saver
 The watt saver cycle is 21601 min (~15 days) equals 100 %. The active time using the watt saver is 1 min.
 $21601 \text{ min} = 100 \%$, $1 \text{ min} = X \%$,
 $X = (1) * (100) / 21601 = 0.004629 = \sim 0.005 \%$
- AC/DC Converter plus the Watt Saver Average power Consumption No Load
 The watt saver cycle is 21601 min (~15 days) and Watt Saver wastes 6.5 mA for 1 minute, while super cap is charging.
 AC Mode current consumption— $0.0065 \text{ A} * 1 \text{ min} = 0.0065 \text{ A} * \text{min}$
 Low Power Mode current consumption— $0 \text{ A} * 21601 \text{ min} = 0 \text{ A} * \text{min}$
 Total current consumption— $0.0065 \text{ A} * \text{min}$
 Average current consumption— $0.0065 \text{ A} * \text{min} / 21601 \text{ min} = 0.000000301 \text{ A}$

Average power consumption

$$P = IV, \text{ so } P = (0.000000301 \text{ A}) * (110 \text{ V}) = 0.000033 \text{ W} = 0.033 \text{ mW}$$

- Power Saving Percent

The discrete AC/DC converter consumes 132 mW while there is no load condition, implementing Watt Saver to this AC/DC converter only consumes 0.033 mW

$$132 \text{ mW} = 100 \%$$

$$0.033 \text{ mW} = X \%$$

$$X = (0.033) * (100) / 132 = 0.025 \%$$

This means that it only consumes 0.025 % or a power saving percent of 99.97 %

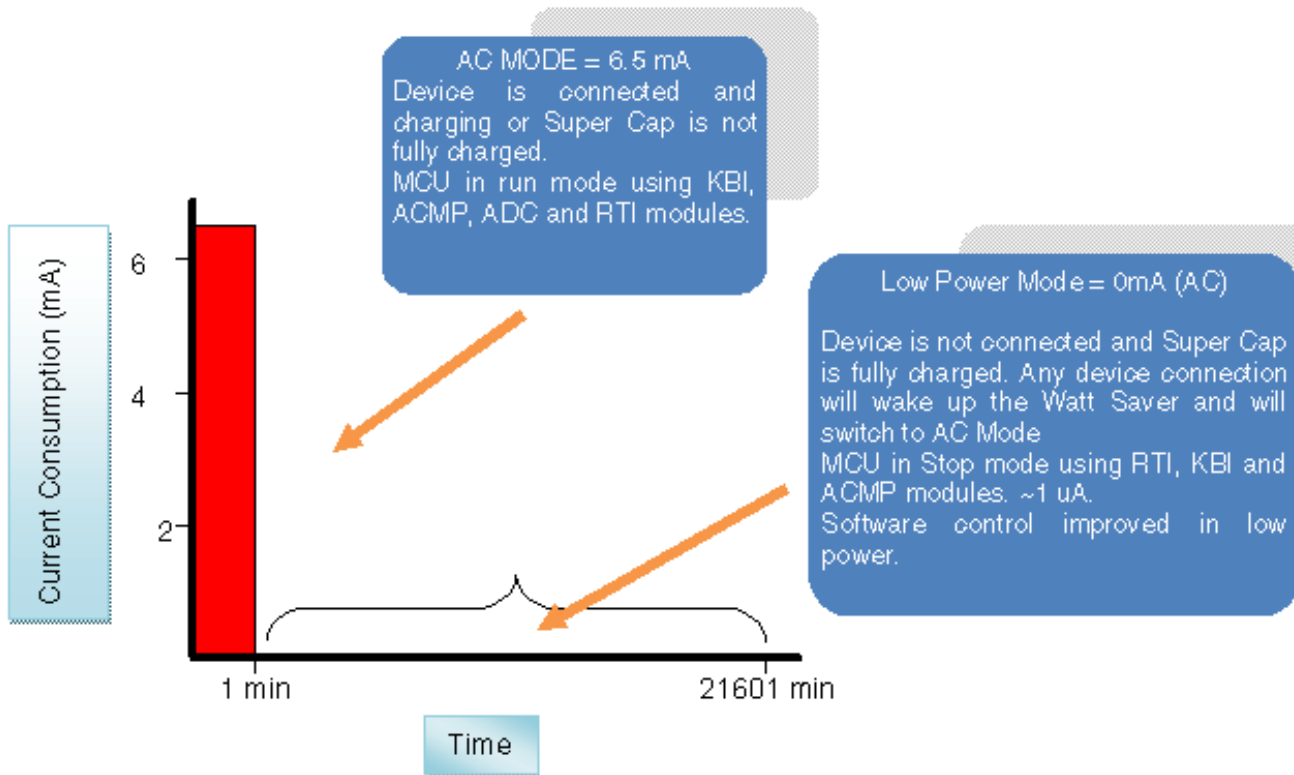


Figure 6. Current consumption

4.7 Troubleshooting

Old devices do not perform the union between GND and shield (GND–shield), this is why these devices do not charge and the LED remains turned off. This condition can be solved by pressing the push button located at the top side of the board, next to the MCU. However, when the device is fully charged, the Watt Saver switches to low-power mode and will start saving energy.

Connect a device using a cable without GND-shield union (USB Adapter).

When you plug a device with this kind of cable, the Watt Saver can not recognize the connection and ignores the device. Press the push button and the Watt Saver switches to AC mode. It then performs a current measurement and if the device battery is discharged, then the Watt Saver will start charging it.

Unplug the Watt Saver from the power line while charging a device.

Conclusions

When you unplug a watt saver from the power line it switches to wait cable mode because a device is connected but not charging, the LED remains turned on, then it will switch to AC mode periodically until the device stops providing current for the Watt Saver or until the device is unplugged.

Device is fully charged but the watt saver does not switch to low power mode, the LED remains turned on.

This occurs when a device is out of the operation range of the current measurement circuit. It is when the device is fully charged and current consumption is higher than 25 mA AC. In this case, the only solution is to unplug the device from the Watt Saver. You can modify the current measurement parameters using the Watt Saver Processor Expert Component. See the user guide document titled *Watt Saver Software Component User Guide* (document number WSSCUG) to configure these parameters.

5 Conclusions

This document described the basic steps for getting started with the watt saver demo board. For technical details about the board design and solution implemented, please check the documentation section in the following website:

www.freescale.com/wattsaver

6 References

- RS08KA: 8-bit General Purpose Ultra-Low-End Market KA MCUs, available at www.freescale.com/RS08KA
- Watt Saver Solution for Chargers, at www.freescale.com/WattSaver
- *Watt Saver Software Component User Guide* (document number WSSCUG), available on freescale.com

7 Revision history

Revision number	Date	Changes
2	10/2013	Initial public release



How to Reach Us:

Home Page:

freescale.com

Web Support:

freescale.com/support

Information in this document is provided solely to enable system and software implementers to use Freescale products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits based on the information in this document. Freescale reserves the right to make changes without further notice to any products herein.

Freescale makes no warranty, representation, or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Freescale data sheets and/or specifications can and do vary in different applications, and actual performance may vary over time. All operating parameters, including "typicals," must be validated for each customer application by customer's technical experts. Freescale does not convey any license under its patent rights nor the rights of others. Freescale sells products pursuant to standard terms and conditions of sale, which can be found at the following address: freescale.com/SalesTermsandConditions.

Freescale, the Freescale logo, and Processor Expert are trademarks of Freescale Semiconductor, Inc., Reg. U.S. Pat. & Tm. Off. All other product or service names are the property of their respective owners.

© 2010-2013 Freescale Semiconductor, Inc.

Document Number
WATTSVERNUG
Revision 2,10/2013

